CHAPTER 7

Quality Control of GEOSAT Wave Data for Engineering Applications

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Introduction

Engineers are often confronted by a paucity of useful wave data needed for a variety of applications. Available information is presently derived from three sources: wave buoy measurements, wave model calculations, and ship observations. Of these, buoy measurements constitute the only reliable data source. However, they provide exceedingly sparse spatial resolution. (For instance, there are only about 45 wave buoys in operation in US waters (Franklin 1992)). Wave modeling (with models such as WAM and the Army Corps' Wave Information Studies) provide a data base of uniform spatial and temporal resolution, but despite many advances, wave modeling must still be considered an evolving field and model results are not fully reliable. Visual ship observations have been used to construct global wave climatologies (e.g. the US Navy Marine Climatic Atlas of the world). However, ship-reported wave observations are irregular and usually regarded as highly imprecise.

This difficulty with traditional data sets may be overcome to some extent by using the large amounts of data collected in recent years by satellites (GEOS-3, SEASAT, Geosat etc.). The US Navy satellite GEOSAT has recorded ocean wave data for almost 5 years. Circling the globe about 15 times a day, GEOSAT gave the densest coverage compared with all existing data. After the initial 18 months of its mission (31 March 1985 to 30 September 1986), it was maneuvered into an exact repeat mission (ERM; November 1986 to January 1990), when the satellite executed 17-day repeat cycles. Global oceanographic information for some 30 oceanographic parameters were recorded every second. These data have been processed by the National Ocean Service (Cheney et al. 1991a, b) and are disseminated to the user community on CD-ROM's. The data are in the form of "Geophysical Data Records" (or GDR's) for the ERM period and "Crossover Difference Records" (or XDR's) for the initial 18 month period. Significant wave heights (SWH) measured by an on-board altimeter were calculated as an average of 10 values recorded every second. About 50,000 measurements, made every 6.4 km along track, were reported daily.

The quality of GEOSAT SWH measurements has been examined by Dobson et al. (1987) and others by comparing them with buoy data. The agreement has been found to be generally good. Of course satellite measurements do not always coincide

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with buoy measurements in space and time, and allowing various windows of separation, they report the following differences (not "errors" but differences):

Max Distance	Separation Time	Average Separation	Separation Time	Difference in rms	SWH mean
50 km	30 min.	35 km	15 min.	0.49 m	0.36 m
50 km	15 min.	35 km	8 min.	0.1 m	
20 km.	30 min.	14 km	15 min.	0.2 m	

Table 1: Comparison of satellite and buoy wave heights (after Dobson et al. 1987)

It is clear that when the two measurements coincide in space and time, the difference between satellite and buoy measurements of significant wave heights are insignificant, at least for most practical uses. Dobson and Porter (1989) and Young (1994) have used these data for their global climatological studies.

In spite of the above observations, there remains some uncertainty regarding the accuracy of GEOSAT SWH data as disseminated to the user community on the CD-ROM's, especially in regions close to land. No comparison has been made with wave data close to land. A closer inspection of the GEOSAT SWH dataset performed here indicates that it contains several erroneous values. Some of the reported measurements are extremely large and have the potential to adversely influence wave statistics calculated on the basis of this dataset (Panchang et al. 1997). In addition, the unintentional use of faulty data on the CD-ROM's is likely to hinder other applications of these data e.g. wave model/data comparisons.

A rigorous assessment of the quality of the GEOSAT SWH data was therefore performed. As noted by Young (1994), quality control of satellite data is difficult; this work involved manual inspection of the satellite and buoy data on a track-by-track basis. This is necessary to eliminate erroneous records from the dataset and to prevent inclusion of similar erroneous records from future satellite missions. A computer program was developed in this study to (a) conveniently extract SWH data in any desired region from the CD-ROM's (since they use a format which is somewhat cumbersome for routine use), and (b) apply rigorous quality control criteria to the SWH data.

Existing Quality Control Criteria

Several quality control criteria were used during the processing of the satellite altimeter data prior to installation on the CD-ROM's (Cheney et al. 1991a, b). Laxon & Rapley (1987), Brooks & Lockwood (1990) and Hayne & Hancock (1990) also describe techniques to flag data of poor quality as measured by SEASAT & GEOSAT satellites. However, these techniques apply to the sensory data records, i.e. the raw satellite data which are not generally available; even if they were, it would be extremely tedious for the user to reprocess the raw data. This study deals only with the data as presented to the end-user on the CD-ROM's. For assessing the quality of the these SWH's, the parameters given in Table 2 (out of the 34 oceanographic parameters presented in the GDR's) are of relevance to this study.

During previous studies that have utilized Geosat wave data, some effort had been devoted towards quality control. For instance, Dobson and Porter (1989) discarded those GDR's which had the following criteria: (1) $\sigma h > 10$ cm; (2) the height bias and satellite attitude were out of range, as determined from bit 2 in the

"Flags" parameter; (3) no value of attitude was available on the GDR (attitude = 0); (4) any one of the 10 per second heights was flagged as bad (as determined by bit 3 in the "Flags" parameter). See Table 2 for a definition of the symbols.

Similarly, in a comparison of wave model and satellite data, Romeiser (1993) used the following criteria to discard measurements: (1) attitude is outside the interval between 0.25° and 1.2°; (2) AGC < 18 dB; (3) σ0 < 6 dB; (4) σswh > 12 cm. In the remainder of this paper, the above criteria will be referred to as the D&P criteria and the R criteria, respectively. Young (1994) also has used certain quality control criteria in his global climatological studies using the ERM data. His criteria, however, are based on the examination of 50 consecutive records, which tend to eliminate large quantities of coastal wave data.

Date, Time	Provided in the Universal Time Constant format.
Latitude	Latitude in degrees (positive for north, negative for south).
Longitude	Longitude in degrees (positive for east, negative for west).
H	1-second average sea surface height derived from 10 per second heights recorded.
σh	Standard deviation from a linear fit to the 10 per second sea surface height values used in computing H.
SWH	Significant wave height as an average of 10 values recorded in one second.
σswh	Standard deviation of the 10 per second wave height values used in computing SWH.
AGC	Automatic gain control determined onboard the spacecraft at a rate of 10 per second. Indicates signal strength at the altimeter receiver.
σagc	Standard deviation of the 10 per second values used to compute AGC
σ0	Backscatter coefficient computed from AGC. Also referred to as normalized radar cross section
Flags	A 16 bit integer, where each bit conveys information about the GDR; of these the following are relevant here: bit 0 = 1 if over water (based on a 1/12 degree mask) or 0 if over land; bit1 = 1 if over water depth over 1000 m. bit2 = 1 if there is height bias reported bit3 = 1 if any of 10 per second values of surface height are bad, (marked 32767)
Attitude	Spacecraft off-nadir orientation angle estimated by ground processing of the return waveform trailing edge.

Table 2: Partial list of GDR parameters (after Cheney et al. 1991b)

In a study of the GEOSAT wave data in the Gulf of Maine, it was found that the above criteria were inadequate. A rigorous examination was therefore performed of the satellite measurements in this region in conjunction with data from several buoys. The Gulf of Maine is particularly well-suited to this study because of the availability of 5 buoys which were operational during the satellite mission and their relative proximity to the satellite tracks (Fig. 1). The adequacy of the D&P and the R quality control criteria was examined and new criteria were developed as necessary. A computer program was then developed to automatically eliminate questionable data. The new criteria and the program were then tested against satellite data in the Gulf of Mexico (Fig. 2).

Wave Data in the Gulf of Maine

There are 14 tracks pertaining to the ERM period of the Geosat mission in the Gulf of Maine. Ascending tracks are denoted here by 0a, 1a, 2a, _ _ _ 7a and descending tracks are denoted by 0d, 1d, 2d, ._ _ _ 5d (Fig. 1). However, the GDR's associated with tracks 0a, 7a, and 0d were found to contain negligible quantities of data in the Gulf of Maine and were hence not used for assessing the quality of the SWH's. It must be noted that even during the ERM phase, the tracks were not exactly self-repeating. As determined from the GDR's, successive passes have a small lateral displacement. Therefore, the lines denoting the tracks in Fig. 1 actually represent a group of closely-clustered tracks. For assessing the quality of the satellite wave measurements, data for the following wave buoys were obtained from NDBC on CD-ROMs (Franklin, 1992): Buoy 44005 (42.7° lat, 68.3° long), buoy 44007 (43.5° lat, 70.1° long), buoy 44008 (40.5° lat, 69.5° long), buoy 44011 (41.1° lat, 66.6° long), and buoy 44013 (42.4° lat, 70.8° long).

As seen in Fig. 1, the satellite tracks never coincide with the exact location of the buoys. Moreover, buoys provide SWH's every hour, while the satellite provides them every second. Therefore, there is never an exact overlap of the measurements for comparison. Automatic comparison of the measurements is thus not sufficient for quality control of the satellite data; differences in the measurements may be entirely attributable to the space/time offset. It was therefore necessary to perform a manual comparison, using as much data as possible as well as a significant level of individual judgment for accepting or discarding satellite data. A complete listing of the satellite data on a track-by-track basis along with the buoy data at the nearest half-hour in the vicinity of the satellite tracks is given in Siddabathula and Panchang (1996).

Quality Control of Satellite Data in the Gulf of Maine

We first performed a detailed examination of the data from the track 2d. The 33 ERM tracks belonging to this class emanate from the west of the Bay of Fundy and proceed southwest past the Cape Cod (Fig. 1). A typical satellite pass in Gulf of Maine region reported 40 to 80 measurements. This variation was due to the fact that sometimes the satellite started tracking several seconds after emerging over water relative to the rest of the tracks in this class. Immediately after emerging over water from west of the Bay of Fundy, the satellite flew over a group of islands; similarly, proximity to land was also encountered near the Cape Cod area. Data from these tracks were examined in detail in conjunction with data from buoys 44005, 440007, 440013 and 44008. Buoy 44011 was considered to be too remote for validation of the data from track 2d.

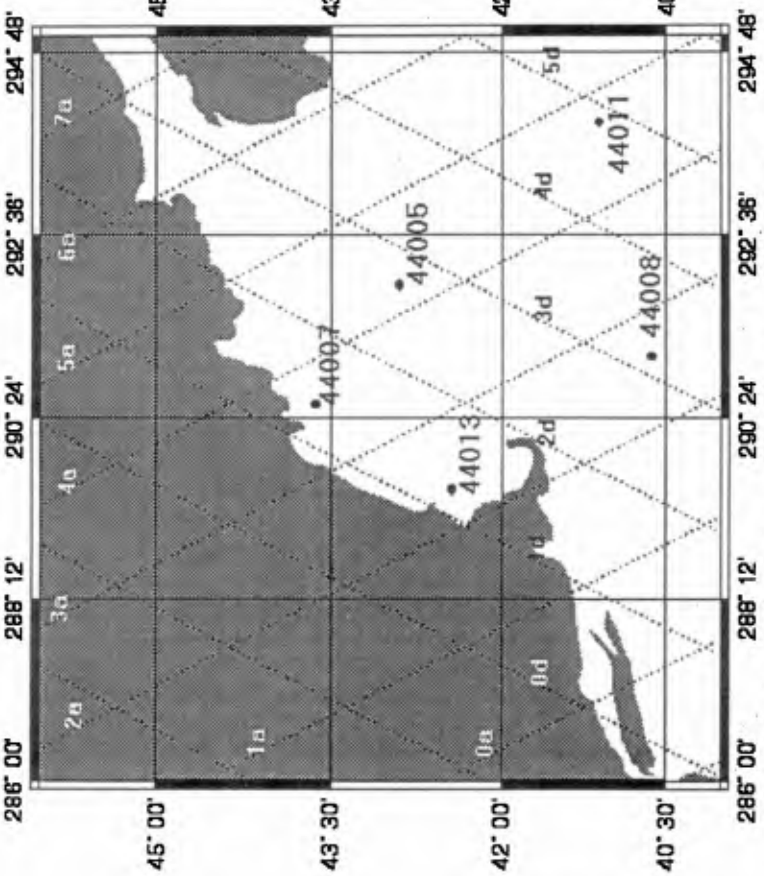

Fig. 1 Geosat Satellite ground tracks and buoys in the Gulf of Maine

The D&P criteria would have detected a total of 99 erroneous measurements; this amounts to 5% of the GDR's (See summary Table 12). Detailed visual examination of these data revealed, however, a number of additional erroneous data records. The R criteria, on the other hand, eliminated almost 50% of the GDR's in this class of tracks (Table 12). There were instances (e.g. the track on 2 March 1987, Siddabathula and Panchang, 1996) where a complete track was flagged as erroneous by the R criteria while visual examination showed that the altimeter data did agree very well with buoy measurements (Siddabathula, 1996). It can therefore be inferred that the R criteria are too stringent for the 2d tracks. The D&P criteria (all but the third) were therefore used as a baseline. Errors which escape detection by the D&P criteria appear to fall in 3 categories for the 2d tracks. These are denoted as E1, E3 and E4. These errors and ways to detect them are described below.

Error type 1 (E1): Consider the following record pertaining to the 2d track (a complete listing can be found in Siddabathula and Panchang, 1996):

Date	Time	Latit.	Longit.	σ h	SWH	σ swh	bit0	bit1	bit2	bit3
				(cm)	(m)	(cm)*				
870109	222251	41.677	290.117	365	0.29	27	1	0	0	0
870109	222253	41.570	290.045	8	10.17	73	1	0	0	0

Table 3: Subset of 2d track data for 9 Jan 1987

At the closest half-hour, the buoys measurements were about 1.5 m (Table 4):

Buoy	Closest Distance from track (km)	SWH(m)
44005	58	1.5
44007	99	0.3
44008	97	1.5
44011	248	2.5
44013	94	0.2

Table 4: Buoy-SWH data for 9 Jan 1987 in the Gulf of Maine.

Clearly the satellite measurement of 10.17 m appears to be in error. This error would not have been detected by the D&P criteria. (Although detected by the R-criteria since $\sigma swh \geq 12$ cm, this criterion, on its own eliminates too many acceptable GDR's, as seen in Table 7). This error appears to stem from a jump in the recording sequence, i.e. no measurement is reported for some time (1 sec in this case, more in some other cases). This may be due to the altimeter shutting off for an interval of time or due to criteria that prevented any faulty data during this time from being installed on the CD-ROM's in the first place. Such errors were found more than 10 (tracks) times out of 33 inspected. Wave heights seemed erroneous each time such a gap in sequence is detected. To automatically detect such faulty data, we have routinely eliminated the first reported record after a gap in the time sequence.

Error type 2 (E2): To be disregarded (Siddabathula, 1996).

Error type 3 (E3): Consider the subset of 2d track data for 16 July 1987 shown in Table 5 (reproduced from Siddabathula and Panchang, 1996). The SWH measurements reported by nearby buoys are shown in Table 6:

Date	Time	Latit.	Longit.	σh	SWH	σswh	bit0	bit1	bit2	bit3
870716	114257	41.176	289.769	23	12.51	51	1	0	0	0
870716	114258	41.122	289.733	141	2.53	25	1	0	0	0
870716	114259	41.069	289.697	324	19.92	0	1	0	0	0
870716	114300	41.016	289.661	39	17.80	79	1	0	0	0
870716	114301	40.962	289.626	13	13.56	51	1	0	0	0
870716	114302	40.909	289.590	10	12.33	42	1	0	0	0
870716	114303	40.855	289.554	5	11.63	39	1	0	0	0
870716	114304	40.802	289.519	6	7.55	22	1	0	0	0
870716	114305	40.748	289.483	5	5.47	13	1	0	0	0
870716	114306	40.695	289.448	4	3.33	7	1	0	0	0

Table 5: Subset of 2d track data for 16 July 1987.

Buoy	Closest Dist. from track (km)	SWH(m)
44005	59	0.8
44007	99	0.2
44008	85	0.8
44011	248	-
44013	94	0.4

Table 6: Buoy-SWH data for 16 July 1987 in the Gulf of Maine.

After careful inspection, it appears that SWH data in all GDR's except the last one are suspect. The first five SWH measurements in Table 5 are discarded by D&P criterion #1. It was also noted that the average SWH is about 1.5m - 2m in the remainder of the track (Siddabathula, 1996). With buoy data showing waves smaller than 1 m, it appears that the last 5 records in Table 5, with SWH of the order of 5.4 m to 12.33 m, are probably erroneous. Also, these records have an σswh > 12cm. The SWH measurement returns to normal once the σswh value falls below 12cm, which in this example, occurs for the last record. This phenomenon of consecutive erroneous SWH measurements occurred especially in descending tracks. It mostly occcurred at the beginning of the 2d tracks and in the proximity of Cape Cod area.

This example is indicative of a typical descending satellite track near coastal regions. This error has occurred about 24 times (72%) out of total 33 tracks. The threshold value of 12cm for σswh was chosen on the basis of visual inspection. For quality control, all GDRs with σswh ≥ 12cm occurring immediately after a series (one or more) of GDRs with a land flag or a GDR with σh > 10cm were regarded as faulty.

Error type 4 (E4): It was found that a GDR has an erroneous SWH measurement if σh is equal 10 cm. Consider the following subset of GDR's (Table 7):

Date	Time	Latit.	Longit.	σh	swh	σswh	bit0	bit1	bit2	bit3
881226	011611	42.737	290.844	4	2.35	0	1	0	0	0
881226	011612	42.684	290.807	3	2.25	*13*	1	0	0	0
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
881226	011618	42.365	290.583	2	2.29	*0*	1	0	0	0
881226	011619	42.312	290.546	2	2.52	*15*	1	0	0	0
881226	011620	42.259	290.509	7	2.17	*12*	1	0	0	0
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
881226	011634	41.513	289.997	13	5.87	21	1	0	0	0
881226	011635	41.460	289.961	10	4.09	0	1	0	0	0
881226	011636	41.406	289.925	2	2.12	13	1	0	0	0

Table 7: Subset of 2d track data for 26 Dec 1988.

The nearest buoy 44005, about 58 km from the satellite track, has reported an SWH = 2.6 m (not shown). It appears that while the last record in Table 7 represents a viable SWH value, the one above it (4.09 m) may be considered suspect. A closer visual inspection of complete listing of the data for this track indicate waves of about 2m and the fact that σswh = 0 further justifies its elimination. This criterion can be considered as a refinement of the D&P criterion #1. It appears that in coastal regions, this threshold value for σh is necessary to eliminate errors which would escape all the above criteria as well as D&P criteria. This kind of error was observed 5-6 times in 2d tracks.

In order to fine-tune the editing criteria, a detailed examination of data pertaining to 3d and 1d tracks (Fig. 1) was performed. This led to 2 new criteria. Tracks belonging to the 3d class encounter close proximity (the shortest distance being 15 km) with buoy 44005 in the middle and buoy 44008 at the outskirts of the Gulf of Maine. Similar proximity to buoy 44007 (near Portland) and buoy 44013 (near Boston) occurrs for track 1d. Therefore data from these tracks were examined in detail in conjunction with data from buoys 44005, 44007, 44013 and 44008. There are 34 tracks in the 3d class and 17 in 1d class. The reason for the small number of 1d tracks is perhaps its proximity to the coastline and the inherent lateral displacement among passes (as noted earlier), resulting in some passes falling largely on land.

Error type 5 (E5): Consider the partial listing of 3d track data for 21 October 1988 in the Gulf of Maine shown in Table 8. Some GDR's in Table 8 depict SWH's as small as 2 cm. These values do not appear to be consistent with the somewhat rougher sea state in the Gulf of Maine region as deduced from the wave buoy measurements in given in Table 9. These small wave heights are probably erroneous and escape detection by all the earlier criteria. This kind of error is found often, about 10 times out of 34 tracks in the 3d tracks and 7 times out of 17 tracks in the 1d class. Detailed examination revealed that satellite SWH's below 0.2 m are almost always suspect, when compared with the buoy measurements near the track and also with successive measurements in the rest of the track. A GDR is thus marked for elimination if the SWH ≤ 0.2 m.

Date	Time	Latit.	Longit.	σh	swh	σswh	bit0	bit1	bit2	bit3
881021	203208	42.990	292.5	3	32767	32767	1	0	0	0
881021	203209	42.937	292.462	1	0.06	5	1	0	0	0
881021	203210	42.884	292.424	2	0.02	0	1	0	0	0
881021	203211	42.831	292.387	2	0.02	0	1	0	0	0
881021	203212	42.778	292.349	2	0.08	8	1	0	0	0
881021	203213	42.724	292.312	2	0.13	8	1	0	0	0
881021	203214	42.671	292.274	3	0.15	7	1	0	0	0
881021	203215	42.618	292.237	2	0.02	0	1	0	0	0
881021	203216	42.565	292.2	1	32767	32767	1	0	0	0
881021	203217	42.512	292.162	1	0.1	8	1	0	0	0
881021	203218	42.459	292.125	2	0.15	8	1	0	0	0
881021	203219	42.406	292.088	2	32767	32767	1	0	0	0

Table 8: Subset of 3d track data for 21 Oct 1988

Buoy #	Closest Dist. from track (Km)	SWH(m)
44005	39	0.6
44007	198	0.5
44008	15	1.3
44011	149	1.2
44013	194	0.9

Table 9: Buoy-SWH data for 21 Oct 1988 in the Gulf of Maine.

Error type 6 (E6): Consider the following partial listing of 3d track data for reported on 4 July 4 1989 in the Gulf of Maine (Table 10).

Date	Time	Latit.	Longit.	σh	swh	σswh	bit0	bit1	bit2	bit3
890704	144332	40.617	290.873	2	32767	32767	1	0	0	0
890704	144333	40.564	290.837	2	32767	32767	1	0	0	0
890704	144334	40.510	290.802	0	32767	32767	1	0	0	0
890704	144335	40.457	290.767	3	32767	32767	1	0	0	0
890704	144336	40.403	290.732	3	0.22	0	1	0	0	0
890704	144337	40.350	290.697	2	32767	32767	1	0	0	0
890704	144338	40.296	290.661	2	32767	32767	1	0	0	0

Table 10: Subset of 3d track data for 4 July 1989.

In all likelihood, the 5th record in the above table is erroneous, even though the flags field and rest of the parameters (associated with the D&P criteria) do not indicate so. Although reasonable close to buoy measurements (Table 11), this altimeter record may be suspect because the GDR is sandwiched between the other faulty GDRs (having, for example, on board instrumentation error denoted by 32767). Also, the parameter σswh = 0 for this GDR, which is doubtful. Such values are therefore considered erroneous and a criterion (E6) is used to flag them. Automatic detection of such errors is done by checking whether there are one or more "32767" type GDR's or other faulty GDR's preceeding and following (thus sandwiching) the GDR in question.

Buoy #	Closest Dist. from track (Km)	SWH(m)
44005	39	0.7
44007	198	0.5
44008	15	0.7
44011	149	1.1
44013	194	0.3

Table 11: Buoy-SWH data for 4 July 1989 in the Gulf of Maine.

In tracks belonging to other classes in the Gulf of Maine, the behavior of erroneous SWH measurements is similar to that of those associated with 2d, 3d and 1d classes of tracks. A detailed analysis of data belonging to the other classes is therefore not presented. It can also be inferred that the cases discussed so far are representative of the editing criteria needed for data pertaining to satellite wave data covering any region in general. Table 12 gives a summary of the relative performance of each of the editing criteria applied to all the tracks in Gulf of Maine region. It is interesting to note that for tracks 1d & 2a, the new criteira actually eliminate more GDR's than the R criteria which are generally too stringent.

Data Extraction and Quality Control Program

The Gulf of Maine study described above led to the following criteria which were found to successfully and optimally eliminate GDR's (as presented on the CD-ROM's) with erroneous SWH measurements:.

1. $\sigma h \geq 10$ cm. [D&P, R and E4]
2. The height bias and satellite attitude were out of range determined from Flags field bit 2. [D&P]
3. Any one of the 10 per second heights was flagged as bad (Flags field bit 3). [D&P]
4. First record reported after a gap in the time sequence. [E1]
5. All GDRs with σswh greater than or equal to 12cm until σswh falls below 12cm, occurring immediately after a series (one or more) of GDRs with a land flag or a GDR with σh greater 10cm. [E3, R]
6. SWH $\leq$ 0.2m. [E5]
7. Record sandwiched between one or more GDRs above and below with instrumentation errors (32767 in SWH or σswh field) or other faulty GDRs.[E6]

GEOSAT data (during the ERM phase) presented to users on CD-ROM's (Cheney et al. 1991b) are sequential in time. Data for some for 34 oceanographic parameters are presented at intervals of 1 second during the satellite's spirograph-like track. This format is cumbersome if only SWH data for a particular area are needed. (The complexity is greater for the XDR's). To facilitate efficient usage, a computer program was developed to read the satellite data from the CD-ROMs, to filter the data according to the above criteria, and to output a filtered dataset for any rectangular region specified by 4 latitude/longitude coordinates.

track_0d	Total	%	track_1d	Total	%
Records	69		Records	417	
Landpoints(L)	69	100	Landpoints(L)	129	30.94
D&P	0	0	D&P	29	6.95
R	0	0	R	63	15.11
Q.C.Program (E)	0	0	Q.C.Program (E)	73	17.51

track_2d	Total	%	track_3d	Total	%
Records	1982		Records	2694	
Landpoints(L)	62	3.13	Landpoints(L)	0	0
D&P	99	4.99	D&P	69	2.56
R	917	46.27	R	942	34.97
Q.C.Program (E)	265	13.37	Q.C.Program (E)	191	7.09

track_4d	Total	%	track_5d	Total	%
Records	1293		Records	1265	
Landpoints(L)	14	1.08	Landpoints(L)	0	0
D&P	19	1.47	D&P	6	0.49
R	271	20.96	R	428	35.05
Q.C.Program (E)	73	7.81	Q.C.Program (E)	46	3.77

track_1a	Total	%	track_2a	Total	%
Records	1163		Records	738	
Landpoints(L)	72	6.19	Landpoints(L)	205	27.78
D&P	54	4.64	D&P	25	3.39
R	230	19.78	R	60	8.13
Q.C.Program (E)	120	10.32	Q.C.Program (E)	78	10.57

track_3a	Total	%	track_4a	Total	%
Records	3513		Records	3815	
Landpoints(L)	281	8	Landpoints(L)	120	3.15
D&P	25	0.71	D&P	36	0.94
R	465	13.24	R	519	13.60
Q.C.Program (E)	136	3.87	Q.C.Program (E)	105	2.75

track_5a	Total	%	track_6a	Total	%
Records	3964		Records	1528	
Landpoints(L)	97	2.45	Landpoints(L)	0	0
D&P	38	0.96	D&P	222	14.53
R	457	11.3	R	368	24.08
Q.C.Program (E)	131	3.3	Q.C.Program (E)	364	23.82

Table 12: Relative performance of editing criteria applied to data in the Gulf of Maine.

Validation of Data Extraction & Quality Control Program

The quality control program described above was based on data in the Gulf of Maine region (Fig. 2). In order to test the reliabilty and usefulness of the new criteria and the program, the program was applied to satellite wave data in the Gulf of Mexico region, bounded by coordinates [24° N, 268.5° E], [31° N, 268.5° E], [31° N, 274.25° E], [24.2° N, 274.25° E]. There are a total of 24 ERM tracks in the Gulf of Mexico region. Fig. 2 also shows the location of several buoys in this region. This

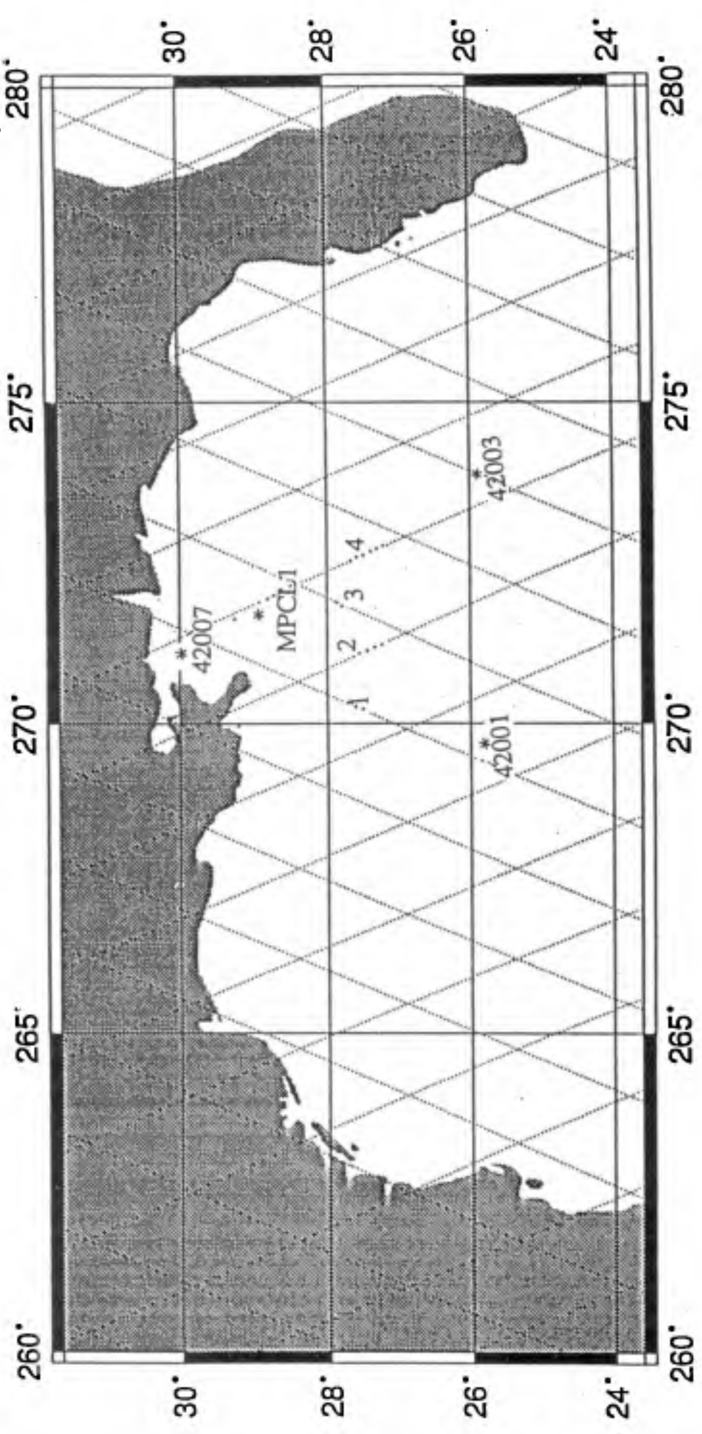

Fig. 2 Geosat satellite ground track and buoys in Gulf of Mexico

region is larger than the primary test site (i.e. Gulf of Maine). For the purpose of validation, data pertaining to 4 ERM tracks (each of which is a cluster of self-repeating tracks in the ERM phase of the satellite mission) falling in the study area were examined in detail. The satellite wave data are compared with measurements from the following 4 wave buoys in this region: 42001, 42003, MPCL1 and 42007. There are a total of 171 tracks, which fall into 4 track classes: 1, 2, 3, and 4 as shown in Fig. 2.

It was found that the program was extremely effective in automatic elimination of questionable data. The D&P criteria would have eliminated only 270 erroneous measurements, allowing several errors to escape detection. The R criteria, on the other hand, would eliminate 2067 records, many of which contain acceptable wave measurements. (In some instances data for the entire pass was discarded by the R criteria, even though most measurements agreed very well with buoy measurements). Application of the program developed here eliminates 1422 data records. The relative performance is given in Table 13. (For additional details, see Siddabathula, 1996).

Statistics for	Gulf Of	Mexico data	Statistics for	Gulf of	Maine data
Records	17414		Records	22441	
Landpoints(L)	322	1.85	Landpoints (L)	1049	4.67
D&P	270	1.55	D&P	622	2.77
R	2067	11.87	R	4720	21.03
Q. C. Progr. (E)	1422	8.17	Q. C. Progr.(E)	1582	7.049

Table 13: Relative performance of editing criteria

Concluding Remarks

The Geosat wave data provide the most exhaustive ocean wave data ever obtained and the potential for using them for a variety of engineering applications (e.g. Panchang et al. 1997) is great. However the dataset available to the user community contain several erroneous wave measurements. Previous efforts at quality control have been largely driven by the synoptic use of these data and have led to criteria that either eliminate large quantities of acceptable data or allow erroneous data to escape detection. Unintentional use of these data can have an adverse influence on various applications. For example, Table 3 shows an SWH measurement of 10.17 m, which, as shown, is probably incorrect and can adversely influence wave statistics calculated with these data (e.g. Young, 1994; Panchang et al. 1997) or data assimilation for wave modeling (e.g. Lionello et al. 1992).

A visual examination of all of the ERM SWH data in the Gulf of Maine on a track-by-track basis in conjunction with wave buoy data led to a set of new criteria which eliminated nearly all the erroneous measurements with minimal loss of acceptable data. A computer program was developed to facilitate SWH data extraction from the CD-ROM's and to perform automatic quality control for any region bounded by 4 latitude/ longitude coordinates. This program may be obtained from the authors.

The criteria and the program were validated by application to satellite wave data in the Gulf of Mexico region. The overall results in Table 13 indicate that the criteria were effective for quality control in the GDR's in both study areas. Application of the program developed here can prevent cumbersome visual inspection of SWH data by users (as done by Young, 1994; Romeiser, 1993). It may be also used for the Geosat Follow-On mission for post-processing the results of existing data-processing algorithms prior to installation on CD-ROMs for the users.

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